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[LITD 8: Electronic Measuring Instruments, Systems and Accessories]

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*Indian Standard*

**TEST PROCEDURE  
FOR GEIGER-MULLER COUNTERS**

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**BUREAU OF INDIAN STANDARDS**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

# Indian Standard

## TEST PROCEDURE FOR GEIGER-MULLER COUNTERS

### 0. FOREWORD

**0.1** This Indian Standard was adopted by the Bureau of Indian Standards on 21 September 1988, after the draft finalized by the Electronic Nuclear Instrumentation Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

**0.2** In testing Geiger-Muller counters, it should be noted that there are at least three different kinds in common use : the 'self-quenched' organic, the 'self-quenched' halogen, and the 'resistor-quenched' halogen. The first two have filling mixtures such that after a discharge is initially terminated, secondary discharges are prevented by the action of quenching agent in the gas mixture. The self-quenched counters exhibit useful plateau characteristics without the use of a series anode resistor. The resistor-quenched halogen counter is self-quenching just above the Geiger-Muller threshold but as the voltage is increased, a transition takes place. Above the transition voltage, the counter is no longer self-quenched and a series anode resistor or external

quench circuit is needed to prevent secondary discharges. For the resistor-quenched counters, it is easier for the user to duplicate the manufacturer's test results if both employ test circuits having a current- or charge-sensitive input. This minimizes the effect of differences in cable and input capacitances.

**0.3** It is necessary to emphasize to both the manufacturer and the user that the operating characteristics have no meaning without specifying the test conditions, such as, associated electronic circuitry, environment, counting rate, etc. As a corollary, the user of a Geiger-Muller counter should not expect to achieve specified operating characteristics if he does not duplicate the manufacturer's test conditions.

**0.4** This standard is based on ANSI/IEEE Std 309-1970 (Reaffirmed 1980) 'IEEE standard test procedure for Geiger-Muller counters', issued by the Institute of Electrical and Electronics Engineers, USA.

### 1. SCOPE

**1.1** This standard covers the test procedure for Geiger-Muller counters.

### 2. TERMINOLOGY

**2.0** For the purpose of this standard, the terms and definitions specified below shall be used.

**2.1 Avalanche** — The cumulative process in which the charged particles accelerated by an electric field produce additional charged particles through collision with neutral gas molecules or atoms.

**2.2 Background Counts (Radiation-Counters)** — Counts caused by radiation coming from sources other than that to be measured.

**2.3 Count (Radiation-Counter)** — A single response of the counting system (*see also 2.31*).

**2.4 Counter Tube, Externally Quenched** — A radiation-counter tube that requires the use of an external quenching circuit to inhibit re-ignition.

**2.5 Counter Tube, Gas-Filled, Radiation** — A gas tube used for the detection of radiation by means of gas ionization.

**2.6 Counter Tube, Gas Flow** — A radiation-counter tube in which an appropriate atmosphere is maintained by a flow of gas through the tube.

**2.7 Counter Tube, Geiger-Muller** — A radiation-counter tube operated in the Geiger-Muller region.

**2.8 Counter Tube, Self-Quenched** — A radiation-counter tube in which re-ignition of the discharge is inhibited by internal processes.

**2.9 Counting Efficiency (Radiation-Counter Tubes)** — The ratio of the number of counts to the total number of ionizing particles or quanta entering the sensitive volume when the counting rate is so low that the dead-time correction is unnecessary.

**2.10 Counting-Rate-versus-Voltage Characteristic** — The relation between the counting rate and the voltage applied to a radiation counter tube for constant radiation intensity.

**2.11 Dead Time ( Radiation-Counters )** — The time interval after the start of an essentially full amplitude pulse during which a radiation counter is insensitive to further ionizing events ( see also 2.25 ).

**2.12 Efficiency ( Radiation-Counter Tubes )** — The probability that a tube count will take place with a specified particle or quantum incident in a specified manner.

**2.13 Gas Amplification ( Radiation-Counter Tubes )** — See 2.14.

**2.14 Gas Multiplication Factor ( Radiation-Counter Tubes )** — The ratio of the charge collected from the sensitive volume to the charge produced in this volume by the initial ionizing event.

**2.15 Geiger-Muller Region ( Radiation-Counter Tubes )** — The range of applied voltage in which the charge collected per isolated count is independent of the charge liberated by the initial ionizing event.

**2.16 Geiger-Muller Threshold ( Radiation-Counter Tubes )** — The lowest applied voltage at which the charge collected per isolated tube count is substantially independent of the nature of the initial ionizing event.

**2.17 Half-Amplitude Recovery Time ( Geiger-Muller Counters )** — The time interval from the start of a full amplitude pulse to the instant a succeeding pulse can attain an amplitude of 50 percent of the maximum amplitude of a full amplitude pulse.

**2.18 Initial Ionizing Event ( Radiation-Counter Tubes )** — An ionizing event that initiates a tube count.

**2.19 Multiple Tube Counts ( Radiation-Counter Tubes )** — Spurious counts induced by previous tube counts.

**2.20 Plateau ( Radiation-Counter Tubes )** — The portion of the counting-rate-versus-voltage characteristic in which the counting rate is substantially independent of the applied voltage.

**2.21 Plateau Length ( Radiation-Counter Tubes )** — The range of applied voltage over which the plateau extends.

**2.22 Plateau Slope ( Radiation-Counter Tubes )** — The slope of the plateau expressed as the percentage change in count rate per 100-volt change in applied voltage.

**2.23 Quenching ( Radiation-Counter Tubes )** — The process of terminating a discharge in a radiation-counter tube by inhibiting re-ignition.

**2.24 Radiation ( Nuclear )** — In nuclear work, the usual meaning of radiation is extended to include moving nuclear particles, charged or uncharged.

**2.25 Recovery Time ( Geiger-Muller Counters )** — The minimum time from the start of a counted pulse to the instant the succeeding pulse can attain a specified percentage of maximum amplitude of the counted pulse.

**2.26 Re-ignition ( Radiation-Counter Tubes )** — The generation of spurious counts by atoms or molecules excited or ionized in the discharge accompanying a count.

**2.27 Resolving Time ( Radiation-Counters )** — The minimum achievable pulse spacing between counts.

**NOTE** — This quantity is a property of the combination of tube and the recording circuit.

**2.28 Rise Time ( Radiation-Counter Tubes )** — The interval between the instants at which the instantaneous value first reaches specified lower and upper limits, namely, 10 and 90 percent of the peak pulse value.

**2.29 Sensitive Volume ( Radiation-Counter Tubes )** — That portion of the tube responding to specific radiation.

**2.30 Spurious Count ( Radiation-Counter Tubes )** — A count caused by any event other than the passage into or through the counter tube of the ionizing radiation to which it is sensitive.

**2.31 Tube Count ( Radiation-Counter Tubes )** — A terminated discharge produced by an ionizing event.

## 2.32 Symbols

$C_{bp}$  = meter bypass capacitance

$C_c$  = coupling capacitance

$C_s$  = stray capacitance or actual component shunting  $R_s$

$C_t$  = detector capacitance

$d$  = collimator diameter

$I_t$  = average current

$K$  = cable ( type and total capacitance )

$l$  = collimator length

$N_1$  = counts per minute at  $V_1$

$N_2$  = counts per minute at  $V_2$

$R_l$  = load resistance

$R_s$  = series anode resistance

$S$  = plateau slope

$t_r$  = rise time ( 10-90 percent )

$t_w$  = pulselength measured at half amplitude

$V$  = supply voltage

$V_t$  = operating voltage

$V_1$  = voltage at the beginning of the plateau ( lower voltage level )

$V_2$  = voltage at the end of the plateau ( upper voltage level )

### 3. TEST CONDITIONS

**3.1 Radiation Background** — During tests, the test area shall be free of all radiation sources other than the normal background and the source being used for the test in progress.

**3.2 Ambient Temperature** — Unless otherwise stated, all characteristics are those at an ambient temperature of 25°C.

**3.3 Radiation Sources** — Most measurement on Geiger-Muller counters are relative measurements and knowledge of the exact source strength is not necessary. Where data is plotted in terms of count rate or current as a function of the exposure rate, a calibrated source is needed. The accuracy of this calibration should be stated.

**3.3.1 Gamma-Ray Sources** — Cobalt 60 shall be used as the gamma-ray source in tests of count rate *versus* exposure rate and current *versus* exposure rate. Additional sources may be used for additional data but the isotopes must be identified.

**3.3.2 Alpha- and Beta-Ray Sources** — A collimated alpha source may be used for probing the thin window ( 1-2 milligrams per square centimetre ) of an end-window counter to determine its radial sensitivity.

A collimated beta source, such as strontium yttrium 90, can be used for radial sensitivity measurements as well as for probing the length of a cylindrical thin-wall beta-gamma counter.

A piece of natural uranium covered with 20 milligrams per square centimetre of aluminium is a useful source for checking end-window counters. This source is specially suitable for comparing the sensitivities of several mica-window counters ( 1-4 milligrams per square centimetre ) of the same type, as no correction need be made for source absorption due to window thickness variations.

**3.4 Geiger-Muller Counter Test Circuits** — Figures 1 and 2 indicate acceptable methods of coupling a Geiger-Muller counter to test or measuring circuits.

Figure 1 shows a positive high-voltage supply and Fig. 2 shows negative high-voltage supply. Geiger-Muller counter characteristics are very dependent on the parameters of the coupling circuit as well as on the input impedance of the associated electronic circuit. The following values must be specified:

- a)  $C_t$ , the counter capacitance;
- b)  $R_s$ , the series anode resistance ( if used, it is usually mounted as close as practicable to the counter anode );
- c)  $C_s$ , the stray capacitance or the actual component shunting  $R_s$ ;
- d)  $K$ , the cable ( type and total capacitance );
- e)  $R_l$  the load resistance;
- f)  $C_c$ , the coupling capacitance;
- g)  $C_{bp}$ , the meter bypass capacitance;
- h) Electronic input:

- 1) Specify type and sensitivity of input as one of the following :
  - i) High impedance-voltage sensitive,
  - ii) Charge sensitive,
  - iii) Current sensitive,
- 2) Provide circuit diagram and component values;
- j) *Operating Voltage* : The direct-current operating voltage must be stated with the specification of counter characteristics. The operating voltage  $V_t$  is calculated from the relationship:

$$V_t = V - I_t ( R_s + R_l )$$

where  $V$  is the supply voltage and  $I_t$  is the average counter current. In most cases, the voltage drop  $I_t ( R_s + R_l )$  is so small that it can be neglected.

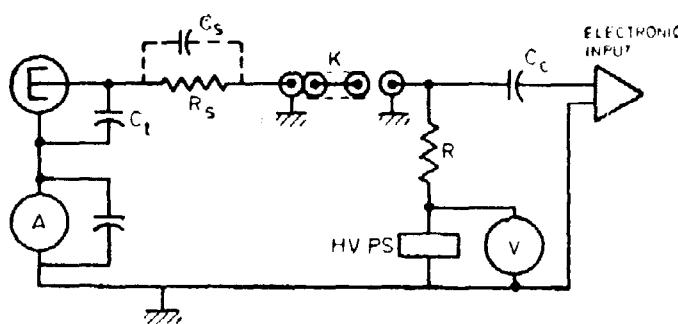


FIG. 1 GEIGER-MULLER COUNTER TEST CIRCUIT-CATHODE AT GROUND POTENTIAL

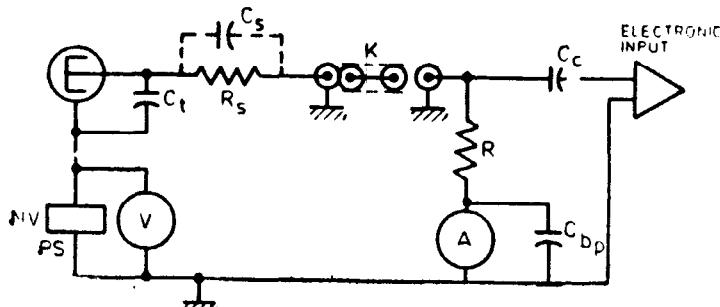


FIG. 2 GEIGER-MULLER COUNTER TEST CIRCUIT-ANODE AT GROUND POTENTIAL.  $C_C$  MAY NOT BE NECESSARY

#### 4. GEIGER-MULLER COUNTER PARAMETERS

**4.1 Background Counting Rate** — The background measurement shall be made with the counter totally enclosed in a nuclear radiation shield. This shield shall consist of an outer layer of lead at least 50 millimetres thick and an inner liner of at least 3 millimetre of aluminium. The background shall be specified as the maximum number of counts per minute.

**4.2 Response to Ionizing Radiation** — The Geiger-Muller counter is connected as shown in Fig. 1 and 2 (see 3.4). The response to radiation will depend on the counter design, the type and energy of the ionizing radiation, and geometric factors which are discussed below. The sources used will depend upon the applications for which the counter is designed. The radio isotopes used for evaluation shall be stated. For counters designed to detect the intermediate range of gamma-ray energies, one of the sources shall be  $^{60}\text{Co}$ .

For each value of ionizing radiation flux, the current and/or counting rate are recorded or plotted at stated operating voltage. This should be done at a count rate for which the product of the dead-time (see 5.2.2) and counting rate is less than 0.05.

A convenient test arrangement for gamma-ray response measurements is the one which employs an unshielded and uncollimated source placed at a distance from the counter, which is several times greater than the largest dimensions of the sensitive area. The counter should not be inside any enclosure and the distance from the room walls and scattering structures should be substantially greater than the dimensions of the sensitive area of the counter. Counter orientation with respect to the source-detector axis shall be stated.

For alpha-, beta-, and X-ray measurements, any geometric factors that could materially affect the evaluation of the counter response shall be described. These factors include angle of incidence of radiation, source shielding and collimation, tube shielding air absorption and absorption due to radiation filters.

**4.3 Geiger-Muller Threshold** — The Geiger-Muller counter is connected as shown in Fig. 1 or 2

(see 3.4) and an oscilloscope is connected in the circuit at the point marked electronic input. The Geiger-Muller counter is placed in a radiation field so that the dead time-counting rate product is 0.05 or less at its rated operating voltage. The voltage is gradually raised from well below the Geiger-Muller threshold until the pulses appear on the oscilloscope. The Geiger-Muller threshold is that voltage at which nearly all pulses are of substantially the same amplitude.

**4.4 Plateau Characteristics** — With the counter in a radiation field, a curve is plotted of counting rate versus counter tube voltage, as shown in Fig. 3. The circuit parameters and the input sensitivity must be stated.

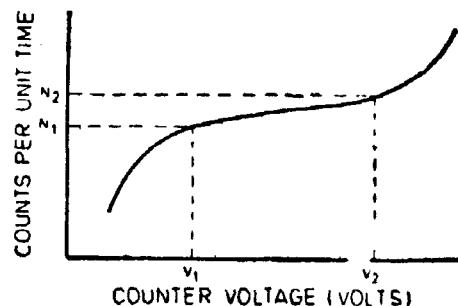


FIG. 3 PLATEAU CURVE-COUNTING RATE Versus COUNTER VOLTAGE

**4.4.1 Plateau Length** — The operating plateau is that portion of the curve which is substantially flat or uniform in slope. The plateau length from  $V_1$  to  $V_2$  of Fig. 3 is expressed in volts and is the region over which the slope is calculated.

**4.4.2 Plateau Slope** — The plateau slope is calculated for the total plateau length specified (see 4.4.1). The slope  $S$  is quoted in percent per 100 volts and can be calculated from:

$$S = 100 \left[ \frac{N_2 - N_1}{(N_1 + N_2)/2} \right] \left[ \frac{1}{(V_2 - V_1)/100} \right]$$

**4.5 Life** — The life of a Geiger-Muller counter is defined in terms of total accumulated counts before certain parameters are changed by a specified

amount. The counter is operated at its specified operating voltage in a radiation field. The circuit used is that of Fig. 1 or 2 (see 3.4). It is desirable that the counting rate be high so as to conserve test time; however, it should not exceed 1/10 of the reciprocal of the dead time (see 5.2.2). When specifying tube life, the extent of change of following specified parameters shall be stated:

- Geiger-Muller threshold,
- Plateau length,
- Plateau slope, and
- Background count rate.

**4.6 Radial Sensitivity (End Window Counter)** — A collimated alpha or beta source may be used to determine the sensitivity along a radius of an end-window counter. The better the collimation, the more accurate the measurement is. If a beta source is used, the source holder must be designed so that the radiation cannot escape from the sides of the source holder. Figure 4 shows a suitable design. The diameter  $d$  and the placement of the collimator should be such that the diameter of illuminated window area is small in comparison to the window diameter. The source is placed as close to the window as practical and then moved across the window along a diameter. Count rate is plotted as a function of the radial position. The source and the collimator geometry shall be stated.

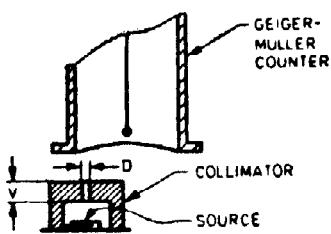


FIG. 4 TEST SETUP FOR RADIAL SENSITIVITY DETERMINATION

**4.7 Longitudinal Sensitivity (Cylindrical Counter)** — In cylindrical counters, the electric field is distorted near each end. The resulting longitudinal dependence of sensitivity can be investigated in a manner similar to that used in 4.6. Count rate is plotted as a function of longitudinal position. The source and collimator geometry shall be stated.

**4.8 Temperature Dependence** — Varying the ambient temperature from the normal room temperature will affect the various parameters of a counter. The amount of change will depend on the type of counter and the temperature difference.

The manufacturer shall specify the operating temperature limits and the change of each affected parameter. If a counter parameter change is approximately linear over the temperature range specified, the change may be expressed as a temperature coefficient. However, if this is not the case, a plot of the change *versus* temperature is necessary.

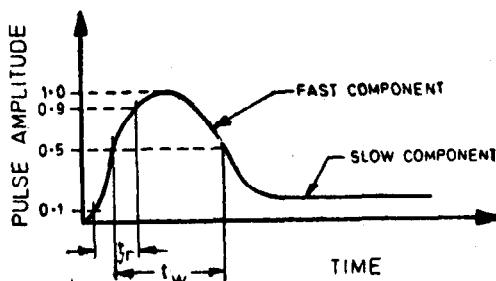
**4.9 Hysteresis** — Some Geiger-Muller counters exhibit a voltage hysteresis effect. Usually this is encountered when determining a count rate *versus* voltage characteristic (see 4.4). There may be a difference in the plateau obtained with an increasing voltage traverse and that with a decreasing voltage traverse. Hysteresis may also be exhibited if a plateau is traversed and the voltage is then set at the operating voltage. This effect is attributed to the charging of insulating surfaces in the counter. Repeated count-rate measurements of a source at a fixed tube voltage should be made to determine if the counter has become stabilized. To test for hysteresis, the plateau shall be traversed in an ascending and then a descending direction with a total elapsed time of less than one hour (much shorter than the charge leakage time constants of the insulating surfaces). The ascending and descending plateau curves shall be shown.

**4.10 Photosensitivity** — The photosensitivity of a counter is indicated by a change in background counting rate on exposure of the counter to light. Since organic quenched counters can exhibit sensitivity to light, they are usually made opaque. Halogen quenched counters usually do not exhibit such sensitivity. Photosensitivity shall be tested by measuring the background counting rate, first with the counter operating in the dark and then with the counter exposed to a stated illumination.

## 5. MEASUREMENTS OF GEIGER-MULLER PULSE CHARACTERISTICS

**5.0** The counter is connected in a circuit such as that shown in Fig. 1 or 2 (see 3.4). The circuit of Fig. 2 is useful in that it may be used without a coupling capacitor between the Geiger-Muller counter and the electronic input. The following characteristics to be measured are dependent on circuitry, counter tube voltage, and counting rate.

**5.1 Current Pulse** — A typical Geiger-Muller counter pulse is shown in Fig. 5. The characteristics of interest are the pulse amplitude, 10-90 percent rise time  $t_r$ , and the half-amplitude pulselwidth  $t_w$ . To observe the current pulse from self-quenched counters, the time constant  $C_t$  times the series circuit resistance  $R_t$  must be short, compared to the current pulse rise time. The current pulse from resistor-quenched counters can be observed if the value of  $C_s$  is a few picofarads. In this case, the amplitude of the observed pulse depends on the relative values of  $C_s$  and  $C_t$ .



**NOTE** — Pulse has not returned to base-line within the time span of this figure.

FIG. 5 TYPICAL GEIGER-MULLER COUNTER CURRENT PULSE

**5.2 Pulse Shape** — Figure 6 illustrates the defined terms that follow. Fig. 6 ( a ) is a drawing made from an oscilloscope picture of the voltage pulse from a halogen Geiger-Muller counter. In general, the rise time is much shorter than the dead time and is, therefore, shown on a different time scale in Fig. 6 ( b ).

**5.2.1 Rise Time** — The rise time of a Geiger-Muller pulse is defined as the time interval between 10 and 90 percent of the peak amplitude. The actual circuit used with component values as well as the voltage on the Geiger-Muller counter must be recorded along with the rise time.

**5.2.2 Dead Time** — The dead time is defined as the time interval after the start of an essentially full amplitude pulse, during which a radiation counter is insensitive to further ionizing events ( see Fig. 6 ). Circuit parameters, counter tube voltage, and counting rate must be recorded along with the dead time. A curve of dead time *versus* voltage is very desirable. When making this measurement, the circuit parameters selected should be such that the

pulse amplitude decreases to less than 5 percent of its maximum value before the succeeding pulse appears. If this condition cannot be achieved, a differentiating network may be used to improve the observation.

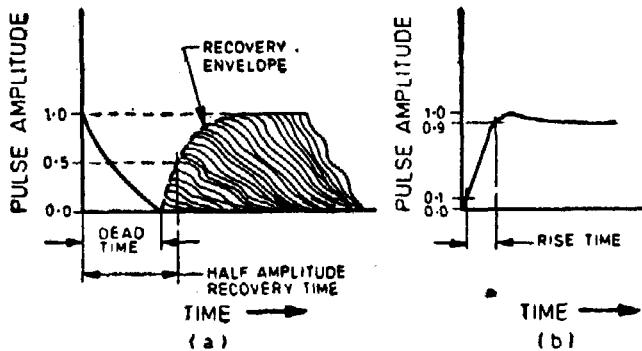
**5.2.3 Half-Amplitude Recovery Time** — The half-amplitude recovery time is defined as the time interval from the start of a full-amplitude pulse to that time when a succeeding pulse can attain 50 percent of the full amplitude. Circuit parameters, counter voltage, and counting rate must be stated along with the half-amplitude recovery time.

## 6. TEST EQUIPMENT

**6.1 Voltmeter** — An electrostatic voltmeter is commonly used as it is a very high input impedance device. A conventional voltmeter or electronic voltmeter may be used provided its input impedance is sufficiently high.

**6.2 Ammeter** — For many halogen-quenched counters, a conventional micrometer of appropriate range may be used to measure the current. Conventional tautband or pivot and jewel types of meters are usually suitable. If the counter current to be measured is too small for a conventional meter, than an electrometer or picoammeter may be used. Regardless of the type of meter or instrument used, the current-resistance drop across it must be sufficiently small so that it does not significantly alter the operating point of the counter. A bypass capacitor ( $C_b$  by in Fig. 1 and 2) should be used across the ammeter to provide an alternating current path to ground.

**6.3 Oscilloscope** — The oscilloscope used should have a triggered horizontal sweep since the pulses are randomly spaced in time. The vertical amplifier should have some built-in delay to permit the observation of initial rise of the pulse. The capacitive and resistive loading effects of the oscilloscope must be considered.



**NOTE 1** — Circuit as in Fig. 2,  $C_t = 4$  picofarads,  $R_g$  and  $C_s = 0$ ,  $R_i = 330$  kilo-ohms oscilloscope shunted by 10 megohms and 7 picofarads.

**NOTE 2** — Writing speed of oscilloscope is such that pulse rise is not visible in Fig. 6 (a).

FIG. 6 OSCILLOSCOPE DISPLAY OF DEAD TIME AND RECOVERY ENVELOPE ( VOLTAGE PULSE )

**6.4 Counting System** — The pulse pair resolution of the scaler should be less than the dead time of the counter being tested. The polarity of the input must be considered as well as the sensitivity, and the instrument must be capable of a wide dynamic range of input pulse amplitudes if satisfactory plateau data is to be obtained. Some scalers include a high-voltage power supply and a preamplifier and if they are not included, some external high-voltage and impedance-matching coupling circuit may have to be provided.

**6.5 Count-Rate Meter** — A linear count-rate meter with manual range change is desirable for making manual or automatic plateau measurements. A logarithmic rate-meter is generally not considered accurate enough for this purpose. The rate-meter ranges must be compatible with the tests to be performed and generally a top range of 100 000 counts per minute is adequate. The input requirements are similar to the ones for the counting-system scaler and must be given the same consideration.

**6.6 High-Voltage Supply** — A variable high-voltage supply that will cover the voltage range of interest

for the counter or counters being tested is necessary. In some cases, this may be an integral part of the scaler or count-rate meter. The supply must be capable of delivering the maximum tube current demanded and must do so without overloading or loss of regulation. The regulation against line and load variations should be one percent or better. The ripple should be less than 100 millivolts.

**6.7 Capacitance Bridge** — It is sometimes desirable to measure the capacitance of a tube or piece of cable. Most counters will have a capacitance of 10 picofarads or less and generally the cable will have a capacitance of less than 100 picofarads per metre. A general-purpose laboratory bridge that can measure capacitance in this range is satisfactory. Some counters contain built-in anode resistors of rather high values ( 1-10 megohms ) and the capacitance of such a counter cannot be measured by the usual bridge. In such a case, the base and the resistor would have to be removed in order to get a meaningful measurement of the capacitance.

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